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ENGINEERING

SYSTEM SOLUTIONS

We at McQuay are very proud of our tradition of producing industry leading water source heat pumps. Our heritage stretches back more that 34 years through McQuay, Singer, Climate Control and AAF brands.

Water source heat pumps remain a revolutionary concept for their simplicity and outstanding energy performance. Products have improved, and so have the ways in which they are applied. For example, geothermal systems can produce unit EERs as high as 36!

This issue of Engineering System Solutions provides a basic overview of why water source heat pumps are so efficient and how steady improvements have made the system fundamentally better. In addition, we look to the future and make suggestions on how to make a great HVAC system even more efficient.

We also provide a brief introduction to McQuay Enfinity™ horizontal water source heat pumps – flexible, high efficiency products that offer the broadest selection of R-410A refrigerant in the industry.

For more information on McQuay Enfinity and other water source heat pump products, contact your local McQuay Representative or visit www.mcquay.com

Hugh Crowther
Director of Applications
McQuay North America

Why Water Source Heat Pump Systems Are So Efficient

Water source heat pump (WSHP) systems share the ability to move energy from where it is not needed to where it is needed with other sophisticated HVAC systems. The energy is moved in water, which is very effective and requires minimal transport (pump) work. Other HVAC systems capable of moving energy around a building include fan assisted VAV and dual duct, dual fan VAV. However, these systems move the energy in air rather than water, which requires ceiling plenums, ducts and fans.

Figure 1 shows how WSHPs can move energy around a building. In a WSHP system, high efficiency, self-contained units can be placed in virtually any location within a building and connected via a water loop. Heat is added and rejected from the loop using a boiler and cooling tower, or by using natural sources such as the ground, a well or a pond. Each unit responds only to the individual cooling or heating load of the individual zone they serve. This results in close control over the temperature and humidity in each building zone, which leads to excellent occupant comfort. Energy use is kept to a minimum because units will generally only operate when there is a call for heating or cooling in their specific zone. In fact, in milder ambient conditions, the units may operate for only a short period of time during occupied hours.

Systems that cannot move energy around the building tend to use electricity to cool one part of the building, and natural gas or another source to heat other parts of the building. While they are not necessarily simultaneously heating and cooling a specific space, the overall building experiences simultaneous heating and cooling.

Most airside HVAC systems employ airside economizers to provide “free cooling”. This requires fan work and may result in spaces being cooled that actually require heat (VAV with reheat at minimum airflow, for example). At the same time, warmer, conditioned air is vented through the exhaust louver, resulting in simultaneous heating and cooling.

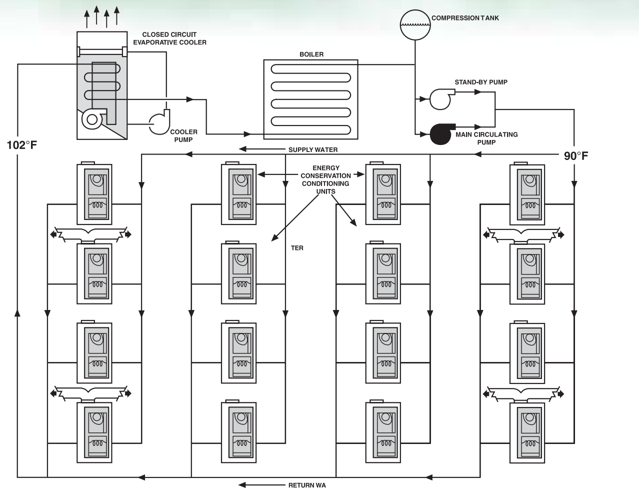
Airside free cooling can also “dry out” a building by introducing large amounts of cold, dry air. Where humidification is a concern (such as colder climates), the cost to humidify the additional free cooling air can be substantial. In many cases, it can be less expensive to operate the chillers in the winter (rather than using airside free cooling) to minimize the humidification load.

Continued on next page.

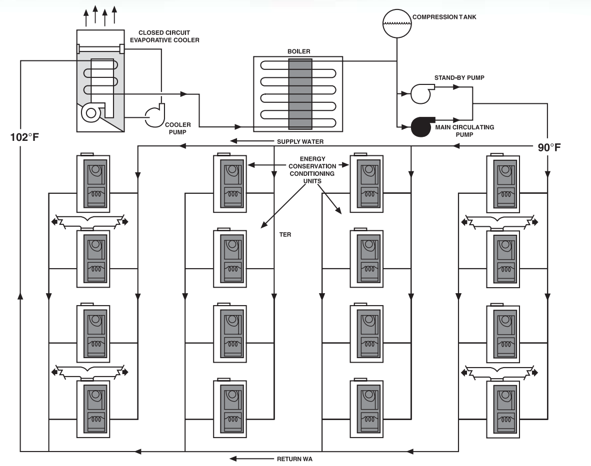
McQuay® Air Conditioning

Figure 1 – WSHP Cooling And Heating Cycles-Boiler/Tower

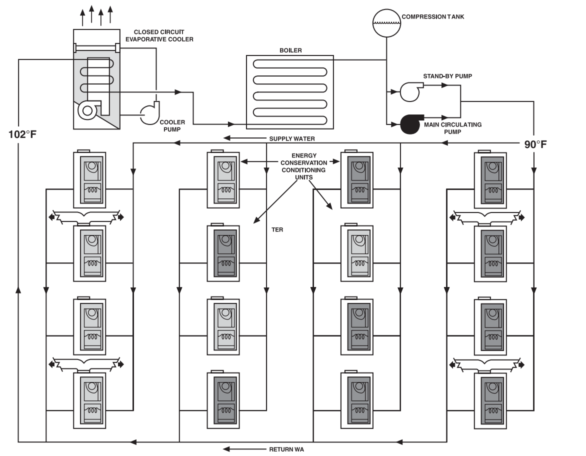
1 During hot weather with most or all units cooling, heat removed from the air is transferred to the water loop. An evaporative water cooler rejects the excess heat outdoors to maintain a maximum water temperature of approximately 90°F (32°C).



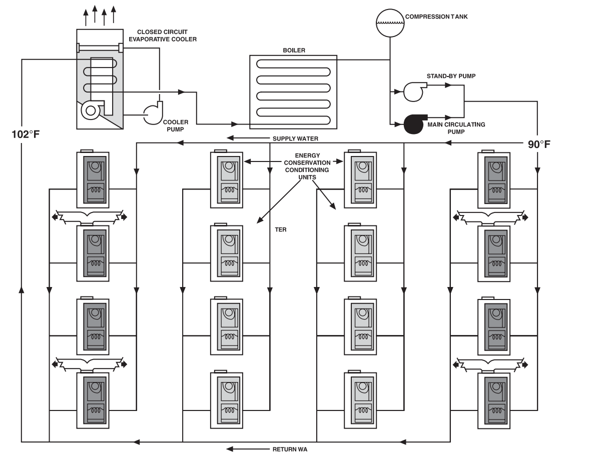
2 Only in very cold weather with most or all of the units heating is it necessary to add heat to the water with a water heater. This is done when the temperature of the water loop falls to 64°F (18°C). The amount of this heat is reduced any time one or more units are operating on cooling. The central water heater is never larger than two-thirds the size required in other systems but is usually less because of diversity.



3 In moderate weather, units serving the shady side of a building are often heating while those serving the sunny side require cooling. When approximately one-third of the units in operation are cooling, they add sufficient heat to the water loop so that neither addition or rejection of heat to/from the water is required.



4 Applications such as office buildings, with high heat gain from lights, people or equipment in interior areas, may require cooling of the space year-round. Heat taken from those areas is rejected to the water loop, providing enough heat for the building perimeter any time at least one-third of the air conditioner's capacity is operating on cooling.



Units on cooling   Units on heating

WSHP System Design

While there are many methods for the designer to overcome some of the shortcomings of other HVAC systems and provide acceptable performance, the WSHP system is one of the most straightforward options available.

Ventilation Design

The ventilation air load of an HVAC system can range from 15% in office buildings to over 30% in schools. Effectively handling the ventilation load is critical if the HVAC design is to be energy efficient. Most WSHP designs use a dedicated ventilation unit to provide the necessary ventilation air for good indoor air quality (IAQ). Only the required amount of outdoor air is introduced to minimize the energy requirement. A dedicated system also allows accurate humidity control and provides the designer with many energy efficient options, such as enthalpy based energy recovery.

Heat Pump Efficiency

Heat pump efficiencies are given in EER or Energy Efficiency Ratios, which is similar to "kW/ton" or COP for chillers. The basic definition is "Tons x 12/ Watts input". In the past, WSHPs were tested to ARI Standard 320 for boiler/tower systems. The ARI standard used the compressor watts and the total fan watts to calculate the EERs. WSHPs are now tested to ISO 13256, an International Standard. When calculating the EER, the ISO Standard takes into account the work due to the pressure drop through the water heat exchanger, the air pressure drop through the air coil (fan work internal to the heat pump) and the compressor work. This means the same heat pump will have different EERs depending on which Standard is used.

Boiler/tower heat pumps operate in a very controlled range, typically between 60°F and 90°F supply water temperature. This effectively provides refrigeration lift requirements similar to water-cooled chillers, which is very efficient.

Does a Heat Pump EER Really Make a Difference?

Less than 20 years ago, the typical heat pump EER was less than 10. Modern, efficient heat pumps, such as McQuay's Enfinity™, have EERs around 15, which is more than a

Boiler/Tower

Surface Water or Lake Loop

50% improvement. To make this point more tangible, consider the following example. A 4-story office building in Buffalo, New York, has 80,000 ft^2 floor area. Built in the early 1980s, it was originally designed with heat pumps that had an average EER of 9.2. The owners are considering replacing the heat pumps and want to understand the capital cost and how long it will take to recoup their investment.

Using McQuay's Energy Analyzer™, the original operating cost is estimated and then the building is re-evaluated with new heat pumps having an average EER of 14.9. Figure 2 compares the savings.

Figure 2 – Comparison of Old vs. New WSHPs

		WSHP	Cooler	Pumps	Ventilation Unit	Total
Base Bldg	kWh/yr	365,798	6,020	87244	135,822	594,884
	$/yr	$ 35,058	$ 577	$ 8,362	$ 5,329	$ 49,326
Hi Eff WSHPs	kWh/yr	265,266	5,380	87,244	135,822	493,712
	$/yr	$ 25,405	$ 515	$ 8,355	$ 4,968	$ 39,243

Replacing the heat pumps reduces the total heat pump energy use by 100,532 kWh and provides $9,275 in annual operating cost savings – a 27% improvement that results in a 4.4-year simple payback for the owner. Even better, the Internal Rate of Return (IRR) is 26.3%, which is very attractive (IRR answers the question, "What interest rate would an owner need at a bank to get the same rate of return that their investment in this project offers?"). It is quite common in the HVAC industry for simple paybacks to be in the 5-year range and IRRs to be in the mid-twenties. It is always a good idea to check the IRR before making financial decisions.

How To Make Heat Pumps Even Better

Variable Flow

Heat pumps move energy around in water with a pump. In the most basic control arrangement, the circulating pumps operate all the time and can quickly add up to be a major energy user. For this reason, ASHRAE Standard 90.1-2001, Energy Standard for Buildings Except Low-rise Residential Buildings, requires that any heat pump system with more than a 10 horsepower pump be variable flow, and that each heat pump have a two position isolating valve that closes when the compressor is not operating (Section 6.3.4. There are exceptions so the reader is advised to review the Standard). Figure 3 shows the savings from converting our previous example to variable flow.

Figure 3 – Variable flow savings

		WSHP	Cooler	Pumps	Ventilation Unit	Total
Hi Eff WSHPs	kWh/yr	265,266	5,380	87,244	135,822	493,712
	$/yr	$ 25,405	$ 515	$ 8,355	$ 4,968	$ 39,243
Hi Eff WSHPs	kWh/yr	265,266	5,380	24,375	135,822	430,843
VF	$/yr	$ 26,165	$ 531	$ 2,404	$ 5,380	$ 34,480

Switching to variable flow reduced the annual pump work by 72% and saved the owner almost $5000/yr. The simple payback for variable flow is 5.5 years with an Internal Rate of Return of 23%.

Ventilation System Enhancements

As mentioned earlier, the ventilation load is a significant part of the load. By using energy recovery (such as enthalpy wheels), the ventilation operating cost can be dramatically reduced. Figure 4 shows the savings that occur when the ventilation system in our example incorporates an enthalpy wheel for energy recovery.

Figure 4 – Ventilation unit with enthalpy wheel energy recovery

		WSHP	Cooler	Pumps	Ventilation Unit	Total
Hi Eff WSHPs	kWh/yr	265,266	5,380	24,375	135,822	430,843
Variable Flow	$/yr	$ 26,165	$ 531	$ 2,404	$ 5,380	$ 34,480
Hi Eff WSHPs	kWh/yr	267,263	5,551	25,611	25,621	324,046
Variable Flow Enthalpy Wheel	$/yr	$25,571	$531	$4,406	$2,451	$32,959

Switching from a DX cool, gas heat ventilation unit to an enthalpy wheel energy recovery system with supplemental gas heat reduced the energy use by 81% (mostly natural gas use). The operating cost improved by over $2,900 per year. Estimating the financial value of energy recovery ventilation units depends on the capital cost. For retrofit applications, upgrading to an energy recovery system will greatly depend on the site conditions. For new construction, the payback is usually around 2 years and the Internal Rate of Return is well above 25%.

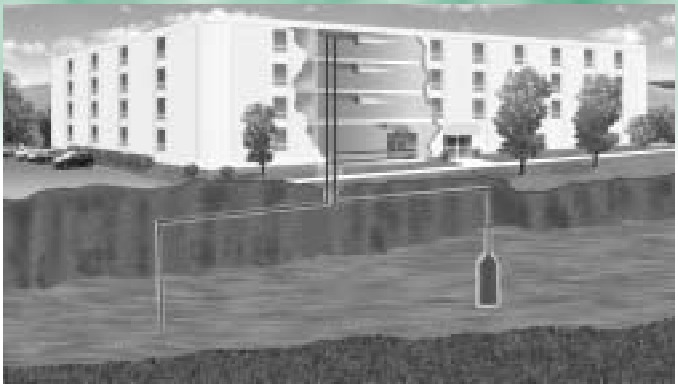
McQuay Rooftop Unit With Enthalpy Wheel

Supply Air

Outside Air

Exhaust Air

Geothermal Closed Loop



Open Loop "Well Water"

Most commercial buildings have a net annual heat gain (They produce more heat than they reject over a year). Heating the ventilation air with energy from the WSHP loop can provide additional savings. A McQuay Templifier™ (a water-to-water heat recovery device) can be used to produce a hot water loop at 160°F with heat from the heat pump loop. The hot water loop can include antifreeze, allowing it be directly used to heat ventilation air.

Geothermal Systems

Geothermal heat pump systems use a ground loop to reject or collect heat from either the ground or a pond. While the design conditions for geothermal systems can have greater extremes than boiler/tower systems (up to 100°F in the

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Moisture Control With Water Source Heat Pumps and Commercial Unitary Products

Both water source heat pumps and commercial unitary products are constant volume, variable temperature HVAC systems. They supply a fixed amount of air to the space and vary the supply air temperature to meet the space heating or cooling load. Since both products use DX cooling, they are generally either on/off or two-stage. With this level of modulation, the space temperature control comes from cycling the unit. For example, if the unit is an on/off type and the cooling load is 50% of design, the unit will operate in cooling 50% of the time.

If the cooling load were only sensible, then this would provide an acceptable level of control. However, if there is a latent load (particularly from outdoor ventilation air) then humidity would be pumped into the space when the unit is off. This can be further exaggerated by the re-evaporation of condensate off the cooling coil and out of the drain pan. Figure A shows the condensate removal and re-evaporation for a 3-ton system. Tests show that until the compressor runs at least 40% of the time, dehumidification is negligible.

The higher the outdoor humidity level, the bigger an issue this can be. For humid climates (such as the Southeastern U.S.), this can lead to excessive humidity levels in space, which can lead to mold growth and serious indoor air quality issues.

Because commercial unitary products integrate the minimum outdoor air damper into the cooling and

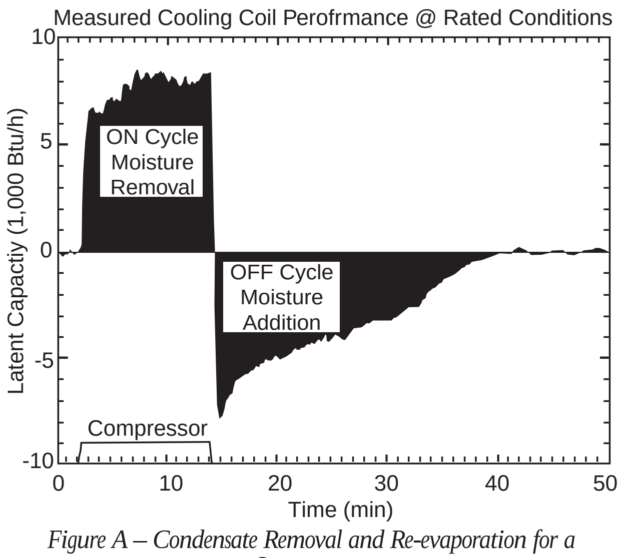


Figure A – Condensate Removal and Re-evaporation for a 3-ton system

heating system, there is the potential to introduce large amounts of moisture into the space. However, heat pump systems typically use a dedicated ventilation unit. The ventilation unit helps remove the moisture from the ventilation air before it ever enters the building envelope so that the heat pumps only handle the sensible load from the space and any internal latent sources. This subtle, but important difference between heat pumps and light commercial unitary products is why heat pumps can offer a better IAQ solution.

References:

[1]*Henderson, H. 1998. "The impact of part-load air conditioner operation on dehumidification performance: Validating a latent capacity degradation model." Proceedings of the 1998 ASHRAE Indoor Air Quality Conference.*

McQuay Enfinity™ Horizontal Water Source Heat Pumps

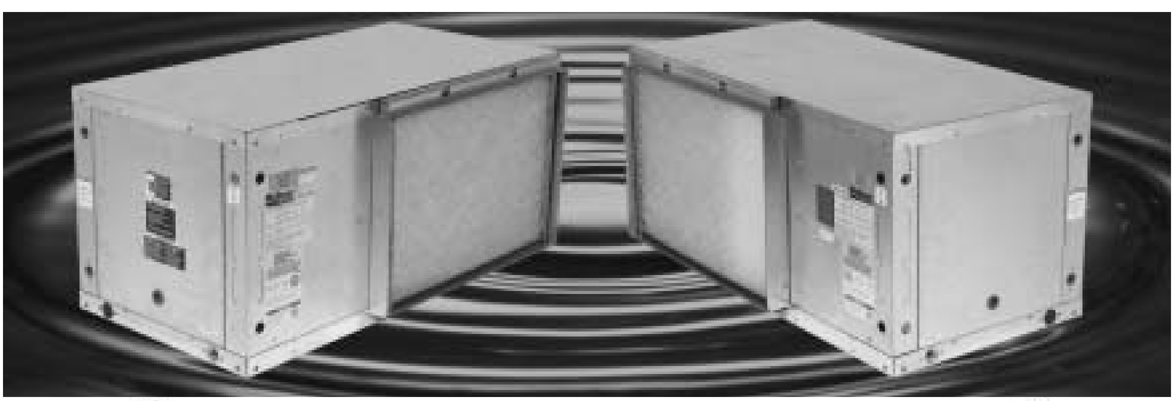
Flexible, High Efficiency and Green

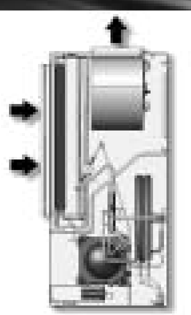
More than 30 years ago, McQuay designed the first complete line of water source heat pumps for high efficiency, individually-zoned comfort control in offices, schools, assisted living facilities, manufacturing facilities and other commercial buildings. Our reputation for outstanding reliability and quiet operation has been reinforced in thousands of successful installations.

McQuay Enfinity water source heat pumps incorporate the best of our past and the best of what's new. Using feedback from building owners, consulting engineers, contractors and service engineers, we designed Enfinity products to give you maximum flexibility to design, operate and maintain the ideal water source heat pump system for your building project. Highlights of features and benefits include:

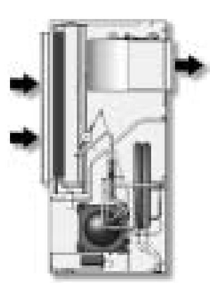
- **Standard range or extended range/geothermal application flexibility.** Extended range units include coil and piping insulation to protect against condensation in low temperature geothermal applications.
- **High unit EERs help reduce operating costs.** All units include a thermal expansion valve and a high efficiency coaxial heat exchanger and blower motor.
- **R-410A refrigerant** (sizes 019 to 060) is a non-ozone depleting HFC refrigerant with an A1 ASHRAE safety classification and no scheduled phase-out date.
- **Left or right return and straight or end discharge configurations** allow you to specify units to fit space requirements and design your system using minimum ductwork and piping. Units can also be field modified to straight or end discharge using interchangeable panels.
- **Four compact cabinet sizes** make it easy to meet the space requirements of new construction or replacement applications.
- **Flexible control options** that include standalone or network operation with the building automation system of choice using LonTalk® or BACnet® communications.
- **Easy maintenance access** to all components and a removable orifice ring that allows the blower and motor to be easily removed while the unit is hanging.
- **IAQ features** including a standard, double-sloped plastic drain pan and optional non-fibrous insulation.
- **Quiet operation** through a large fan wheel and low speed motor operation, heavy gauge construction and vibration-isolated hanger brackets.

Whether you are designing an energy efficient green building, or retrofitting an existing building to lower your operating costs, McQuay Enfinity water source heat pumps offer you the best combination of energy efficiency, compact size, flexibility, low noise, easy control integration, IAQ features and environmentally friendly refrigerants. For more information, contact your local McQuay Representative or visit www.mcquay.com.

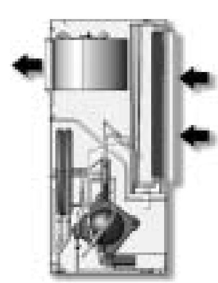




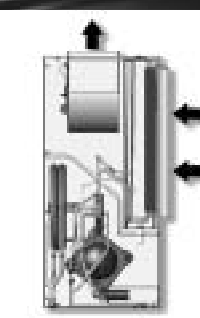
Left return, end discharge



Left return, straight discharge



Right return, straight discharge



Right return, end discharge

summer and 25°F in the winter), the loop water temperature is more moderate on average. Most commercial geothermal heat pump systems have an annual net heat gain, which indicates there is greater need to perform well in cooling than in heating. With the low water temperature found in geothermal systems, the unit EER can be as high as 36!

In addition to a significant energy improvement, there is no boiler or closed circuit cooler in a geothermal system. Figure 5 shows that geothermal systems offer an additional 43% in energy savings, mostly in natural gas use. This equates to almost $9,000/year in operating savings.

Figure 5 – Geothermal Operating Savings

		WSHP	Cooler	Pumps	Vent Unit	Boiler	Total
Hi Eff WSHPs	kWh/yr	267,263	5,551	25,611	25,621	194,286	518,332
Variable Flow	$/yr	$25,571	$531	$4,406	$2,451	$4,574	$37,533
Geothermal	kWh/yr	231,600	N/a	36,356	25,621	N/a	293,577
	$/yr	22,600	$0	$3,568	$2,451	$0	$28,619

Summary

Water source heat pumps are still one of the best ways to air condition a building. Their ability to move energy to where it is needed makes them one of the most efficient HVAC systems available. New improvements to heat pump efficiency have made a good system even better. Modern efficiencies can actually create a business case for owners to replace existing equipment because of the acceptable return on their investment. Providing energy recovery ventilation unit further enhances the system.

Geothermal designs take the fundamental heat pump concept to the next level. In the right application, geothermal heat pump systems offer the best HVAC performance available today.

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